GETTING READY FOR THE A380 AIRCRAFT

AT

HONG KONG INTERNATIONAL AIRPORT

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ABSTRACT

In December 2000, a decision was made by Airbus Industries to undertake the development of the world largest aircraft, the A380. Subsequently, the first A380 flight was successfully conducted in April 2005 in France. Six airlines have indicated their intention to use the A380 aircraft for operations at Hong Kong International Airport and plan to begin operations in late 2007 or early 2008. This paper describes the compatibility study carried out by the Hong Kong Airport Authority to identify the requirements to upgrade the airport facilities to ICAO Code 4F standard. These include the widening of a number of taxiways, the relocation of infringing obstacles, relocation of runway stop bars, the modification of jet blast fences, and the modification of aircraft loading bridges, fixed ground power and pre-conditioned air systems. The paper also describes the various design options that were considered for the upgrade and the difficulties encountered implementing the changes under an operating airport environment.

1. INTRODUCTION / BACKGROUND

The Hong Kong International Airport (HKIA) was opened in July 1998. It has two parallel runways, two passenger terminals and two cargo terminals that currently handle 45 million passengers and 3.5 million tonnes of cargo per annum.

During the design of the master plan for the new airport in 1990-92, the operation of New Large Aircraft (NLA) was taken into account. Based on the information available at the time, the following main dimensional characteristics of the "design aircraft" was adopted.

- Aircraft Length : 85 meters
- Aircraft Wingspan : 84 meters
- Tail Height : 25 meters

The geometry of the two runways and major taxiways was designed to accommodate the operation of NLA. Most of the front stands were designed for aircraft of the dimensions of the B747-400. However, five frontal stands along the eastern side of the Northwest Concourse were specifically dimensioned to accommodate NLA. The twenty one stands on the cargo apron together with their taxi lane have clearances sufficient to accommodate B747-400s or Code E aircraft operations. Of these stands, two were earmarked for future expansion to accommodate A380 aircraft.

In 2004, with the finalization of the A380 aircraft design, the Airport Authority Hong Kong (AAHK) undertook a detailed airport compatibility study with respect to the aerodrome licensing requirements for Aerodrome Reference Code 4F aircraft. The objective of the study was to determine whether HKIA and its facilities could accommodate the A380, as well as future derivations of the A380 or other Code F aircraft. It also defined the changes that AAHK must complete in order to upgrade the current Aerodrome License from an Aerodrome Reference Code 4E to Code 4F.

2. COMPATIBILITY STUDY

2.1 A380 description and performance

The A380 is a subsonic, long range, high capacity civil transport aircraft. Table 1 shows the dimensions of the A380 compared to the B747-400, the largest existing aircraft operating in HKIA, and the Master Plan Design Aircraft, the New Large Aircraft (NLA). Currently the longest aircraft operating at HKIA is the A340-600, with a length of 75.4 meters.

Table 1
Comparison of Aircraft Dimensions

Item	A380-800	B747-400	NLA
Wingspan	79.6m	65m	84m
Length	72.7m	71m	85m
Tail Height	24.1m	19m	25m
Max. Take off Weight (MTOW)	560t Pax/590t F	395t	590t
Outer Gear Wheel Span	14.3 m	12.4m	18.45m
No. of Passengers	555	400	600-900
Range	8,000 nm	6,500nm	N/A

2.2 Comparison between ICAO Standards/recommended practices and HKIA.

Annex 14 Aerodrome Design and Operations

The International Civil Aviation Organization (ICAO) has identified minimum design standards for the safe operation of aircraft at airports. These International Standards and Recommended Practices are published in Annex 14 [1] of the Annex 14 prescribes the physical characteristics and surface obstacle limitation to be provided at airports.

The design dimensions for the A380 (ICAO Code F) and the design criteria at HKIA are compared in Table 2.

Table 2
Airfield Dimension and Separation Criteria

Item	ICAO Code F (Wingspan 80 m x length 80 m)	HKIA Criteria (Wingspan 84 m x length 85 m)
Design Criteria		
Runway Width	60m	60m
Runway Shoulder	7.5m	7.5m
Taxiway Width	25m	29m
Taxiway Shoulder	17.5m	North Runway 15.5 m South Runway 7.5 m
Taxi lane Width	25 m	29 m
Separation Criteria		
Runway /Taxiway	190 m	192m
Taxiway /Taxiway	97.5 m	99 m
Taxiway /Object	57.5 m	57m
Taxi lane /Object	50.5 m	54m

As the table shows, most of the HKIA's airfield dimensions and separation criteria met the current ICAO design standard. However, two of the existing airfield dimensions did not comply to the standards; Taxiway Shoulder and Taxiway - Object separation. The difference in the North Runway taxiway shoulder separation criteria was small, and as the total paved area width is 60 m, equal to the total taxiway pavement width recommended by ICAO, therefore the North Runway is in compliance with the criteria.

The South Runway taxiway shoulders and, in turn, the total pavement width, did not comply with the existing Code F criteria and either needed to be expanded or have operational restrictions imposed on the use of the outer engines of Code F aircraft. Based on the ICAO requirement of a width of 60 m, an 8 m shoulder expansion on each side of the taxiway centerline had to be constructed if alternative operational requirements were not to be implemented.

The taxiway centerline to object separation adopted during the design and construction of the airport was 57 meters. The ICAO Code F taxiway centerline to object separation is 57.5 meters. An airside-wide comprehensive survey was conducted and analysis of the survey data indicated that 49 structures including sign posts, lamp posts, wall structures, jet blast structures and airside roads infringed the ICAO Code F requirements and needed to be relocated.

Runway Length

Annex 14, Volume 1 calls for the calculation of declared distances for a runway intended for use by international commercial air transport and Annex 15 requires the reporting of declared distance in each direction of the runway in the Aeronautical Information Publication (AIP).

The following table identifies the declared distances for each runway at HKIA

Table 3
HKIA Declared Runway Distances

Runway	TORA	TODA	ASDA	LDA
07R	3800 m	4100 m	3800 m	3640 m
25L	3800 m	4100 m	3800 m	3800 m
07L	3800 m	4100 m	3800 m	3627 m
25R	3800 m	4100 m	3800 m	3626 m

Notation: TORA : Take-off runway available

TODA : Take-off distance available

ASDA : Accelerated stop distance available

LDA : Landing distance available.

Although preliminary information on runway length requirements for the A380-800 was published by Airbus in the "Airplane Characteristic for Airport Planning" manual, approved values will only be stated in the operating manuals specific to each airline operating the aircraft. ICAO (Aerodrome Design Manual, Part 1 Runways) have adopted runway length guidelines when the appropriate flight manuals are not available. These guidelines included correction factors based on elevation and temperature.

The first step in the determination of the required runway length was to identify a basic length that meets the operational requirements of the aircraft. This basic length is required for take-off under standard atmospheric conditions, zero elevation, zero wind and zero runway slope. Airbus have identified the following basic runway reference length for take off as:

Take-off length at MTOW, sea level, ISA + 15 C = 2990 meters

Once the basic length has been identified, correction factors can be introduced based on the particular airport elevation and reference temperature. ICAO's elevation correction factor stated that the basic length should be increased at the rate of 7% per 300 m elevation. HKIA's elevation, as identified in the Aerodrome Manual, is 7.0 mPD. Based on this fact, no correction has to be introduced for elevation.

The correction factor for temperature, as identified by ICAO, is increase in basic length of 1% for every 1° C by which the airport reference temperature exceeds the temperature in the standard atmosphere for airport elevation. HKIA's reference temperature is 31.6° C. Based on the runway reference length of 2990 m at ISA +15° C, as identified by Airbus, the basic runway length should be increased by 16.6% (31.6° - 15°C = 16.6°C => 16.6%). With the temperature correction factor, the runway length, at HKIA must be at least 3,487 m to safely accommodate the A380. Since both the north and south runways have a runway length of 3,800 meters, the A380 can be safely operated on both runways.

Width of Curved Taxiways at Junctions and intersections

ICAO specify that the design of the taxiway curve should be such that, when the cockpit of the aeroplane remains over the taxiway centre line markings, the clearance distance between the outer main wheels of the aeroplane and the edge of the taxiway pavement should not be less than 4.5 meters for a Code F taxiway. The design of taxiway curves and the edge of taxiway pavements depends on two aircraft dimensions; the outer main gear span and the wheel-base. The design aircraft adopted for the airfield is based on a generic "New Large Aircraft" (NLA) with an outer main gear span of 18 meters and a wheel-base of 33 meters.

The A380-800 aircraft, which had an outer main gear span of 14.3 meters and a wheel-base of 30 meters, is less than that of the design NLA aircraft. Nevertheless, a comprehensive review of all curved taxiways at junctions and intersections was carried out using the "AutoTurn Aircraft 5" simulation software package to evaluate whether the main gear trace of the A380-800 aircraft complies with the above stated ICAO requirement.

The simulation confirmed that the clearance distance between the outer main gear of the A380-800 aircraft and the edge of the taxiway pavement for all taxiway junctions and intersections was greater than the ICAO requirement.

Runway Holding Point

The runway stop bars were situated at 101 meters away from the runway centre line. This dimension was adopted based on the assumption that a holding aircraft would not infringe the inner transitional surface with the surface' lower edge offset 60 meters from the runway centre line. Although ICAO recommends a minimum hold bar distance from the runway centerline of 90 meters, HKIA adopted a distance of 101 meters to provide adequate buffer time for ATC controllers to react in case of a runway intrusion.

The updated ICAO Annex 14 Third Edition (1999) [1] recommends that the inner transitional surfaces should have its lower edge offset 77.5 meters from the runway centre line and that a Code F aircraft stop bar should be located at a minimum distance of 107.5 meters from the runway centerline. In order to comply with the new ICAO standard, all runway stop bars needed to be relocated by 6.5 meters.

2.3 Pavement Strength

The pavement of the airport was designed using the 1989 PSA "A Guide to Airfield Pavement Design & Evaluation". The north runway pavement was designed using the linear elastic pavement design model LEDFAA from the Federal Aviation Administration. The critical aircraft for the structural design of the airfield pavement was taken to be the B747-400 (at approximately 400 tonnes all-up weight) with a flexible ACN of 72 and rigid ACN of 80. The typical construction details of the runway flexible pavement, taxiway flexible pavement, and rigid pavement in aprons are shown in Figures 1, 2 & 3 below.

The maximum take-off weight of the A380-800 pax aircraft and freighter are 560 tonnes and 590 tonnes respectively. Based on the current medium sub-grade strength declared at HKIA (Category B - CBR 10 and k = 300 pci), verified by a Heavy Falling Weight Deflectometer survey, the ACN for the A380 aircraft and PCN for pavement at HKIA are shown in Table 4.

Table 4
A380 ACN and Pavement PCN

Location	A380 ACN Pax / Freighter	PCN at HKIA
Runway	69/72 F /B	72 /F/B/W/T
Taxiways	69/72 F /B	72 /F/B/W/T
Passenger Aprons	65/69 R/B	80 /R/B/W/T
Cargo Aprons	65/69 R/B	80 /R/B/W/T
Maintenance Aprons	53 R/B	53 /R/B/W/T

The review confirmed that the existing airfield pavement strength at HKIA is capable of supporting the A380 aircraft.

2.4 Ground maneuvering

The tracking for an A380-800 aircraft while exiting the runways via each rapid exit taxiway was checked using the "AutoTurn Aircraft 5" software package. The simulation analysis confirmed that both the cockpit, as well as the nose-wheel, tracking the centerline marking maintain the ICAO required 4.5 meters minimum clearance.

The wing tip clearance of two A380 aircraft at runway departure holding positions was also checked and the ICAO requirement of 7.5 meters minimum clearance was achieved.

2.5 Operating conditions (Jet Blast)

A standard normalized contour plot of jet plumes for B747-400, B777 and A380-800/800F under high breakaway power settings confirmed that the A380-800 and the A380-800F were the critical aircraft in terms of jet plume size. The jet blast plume relative to a 55 km/hr wind speed extends 218 meters behind the aircraft tail. The existing jet blast fences at the airport were designed based on the breakaway jet blast plumes swept paths of the B747 aircraft. A systematic and comprehensive study to simulate the effect of the A380-800F jet blast swept path on the airside areas where the A380 aircraft would operate was carried out. The study concluded that the existing jet blast fences are adequate to protect against the breakaway jet blast effects of the A380 aircraft. However, there were four locations where the breakaway jet blast effect could potentially pose a hazard due to the larger width of the jet plume footprint. The existing jet blast fences at these locations had either to be lengthened or special operational procedures established to safeguard operational safety.

2.6 Ramp Services

The study also reviewed the ramp services requirements of the A380 aircraft including refueling, toilet and waste services, ground electrical power, low pressure preconditioned air, potable water service, and ground service equipment such as catering trucks, cargo loaders and tow-tractors. The identified shortfalls and new requirements were passed on to the ramp handling operators of the airlines for their action. The study also identified the necessity for AAHK to investigate new loading bridge arrangements to serve the upper deck door, U1, of the A380 aircraft.

3. IMPLEMENTATION OF UPGRADING WORKS

3.1 Widening of Taxiway Shoulders

Based on the compatibility study, 27 taxiway shoulders had to be widened by 8 meters each. The total area of the widening works was estimated to be 190,000 m^2 and is scheduled to be carried out in three phases between 2006-2010. The existing pavement structure of the taxiway shoulder is shown in Figure 1.

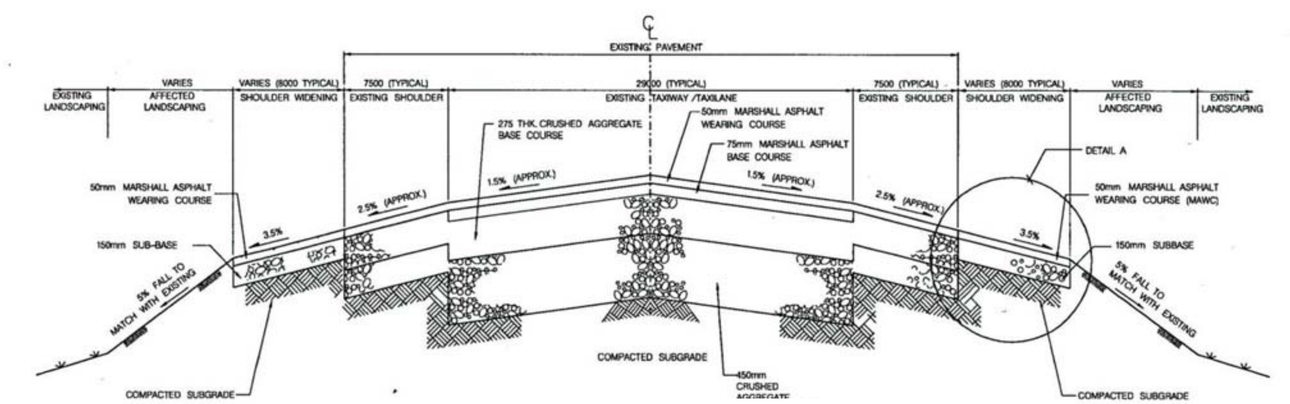


Figure 1 - Typical Taxiway Shoulder Widening Cross Section

The primary function of the widened shoulder is to minimize the risk of damage to engines caused by ingestion of foreign objects. With this in mind and the fact that the shoulders do not support the loading imposed by aircraft, four options were considered. These included asphalt pavement, artificial turf, precast concrete panels and tack coat.

Life cycle cost evaluations, risk assessments and work program implication analyses were conducted on all four options. Based on the results, the asphalt pavement option was finally adopted. The new pavement comprises a 50 mm Marshall Asphalt Wearing Course and a 150 mm Crushed Aggregates Base Course (CABC) on top of the existing compacted subgrade. Run-up slabs were provided at the taxiway /runway junctions. Typical details are shown in Figure 2.

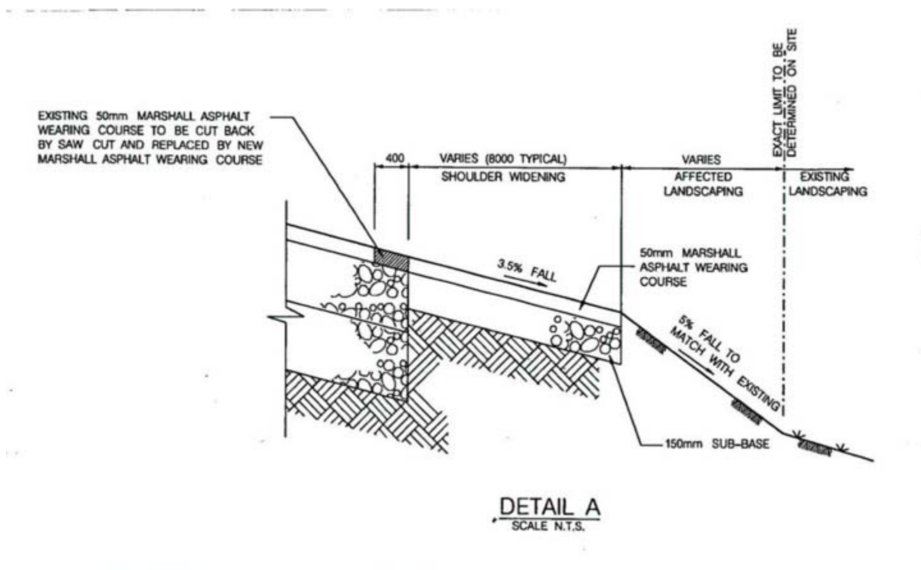


Figure 2 - Taxiway Shoulder Widening Detail

The first phase of the widening works covering Taxiways H, J, V, V1, and W with total area of 108,090 m^2 was completed in 2006. Part of the works were carried out under a special arrangement of partial closures of the taxiways sections to allow for 24 hour work. In critical sections, the widening works had to be carried out during the night closure period between 00:00hrs to 08:00hrs.

Before excavation, utilities defect surveys and trial trenches were carried out to identify existing cables and utilities. Protection or diversions were then carried out as necessary. The existing top soil of 200 mm depth was removed, the subgrade compacted, and a double layer of tack coat was applied followed by the laying of 150 mm CABC. The tack coat was applied on top of the exposed CABC after each work shift prior to handing back the taxiways for operation. The wearing course was laid only after the completion of a substantial area of CABC. At taxiway runway junctions, the existing run-up slabs had to be removed and re-instated after the pavement widening was complete.

3.2 Relocation of Runway Holding Points

Following the findings of the A380 Compatibility Study in 2005, the runway stop bars (for runway entry and runway crossing) were relocated to comply with the minimum distance of 107.5 meter from the runway centreline. A total of 15 stop bars were relocated, nine on the South Runway and six on the North Runway. The existing Movement Area Guidance Signs (MAGS) were also relocated adjacent to the new stop bar locations. Typical details of the stop bar AGL are shown in Figure 3.

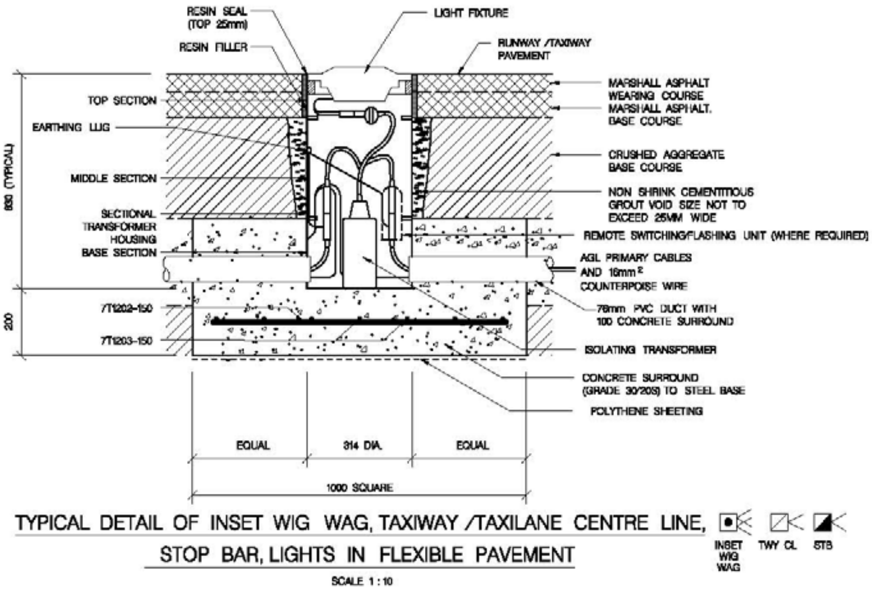


Figure 3.

Construction Constraints

Access to the Southern Runway was granted 5 nights per week (00:30 to 08:30 hours) and to the North Runway, 2 nights per week (01:00 to 08:30 hrs). Areas were required to be operational again after each work shift, with the exceptions of the runway secondary entry whereby 24 hours access was allowed.

Site Constraints

Detailed design revealed that other utilities or drains under the pavement or on the ground clashed with some of the proposed stop bar locations. Hand dug trial pits were carried out to identify problem locations and determine the appropriate construction method.

Construction Method

The conventional cast-in-situ method, as shown of Figure 4, was adopted for relocating those stop bar AGL at the runway secondary entries for which the entire runway entry was closed off and 24 hour work duration was allowed.

Figure 4 - Cast-In-Situ Method on Asphalt Pavement

The pre-cast method as shown on Figure 5, had to be used for relocating those stop bar AGL at the runway preliminary entries for which access was limited.

Figure 5 - Pre-cast Method on Asphalt Pavement

3.3 Modification of Aircraft Loading Bridges in HKIA

The Passenger Terminal Building (PTB) in HKIA is equipped with 49 frontal stands. Five dedicated stands located at the Northwest Concourse were designed to accommodate the New Large Aircraft (NLA). With the development of the A380 aircraft, the boarding bridges at two stands (N60 and N62) underwent a series of modifications to provide passenger boarding and disembarking services to take multi-deck aircraft.

Each of the boarding gates comprises of two apron drive loading bridges with a three-tunnel configuration, specifically designed to provide parallel boarding or disembarkation services for aircrafts. Different modifications options of these loading bridges were considered and the option most compatibles with the A380 implemented.

Operation Modes of Aircraft Loading Bridges for A380

The A380 is the world's first double-deck jetliner with a full upper deck cabin layout for passenger seating. As shown in Figure 6, there are seven passenger doors on each side of the aircraft, 3 on the upper deck and 4 on the lower deck.

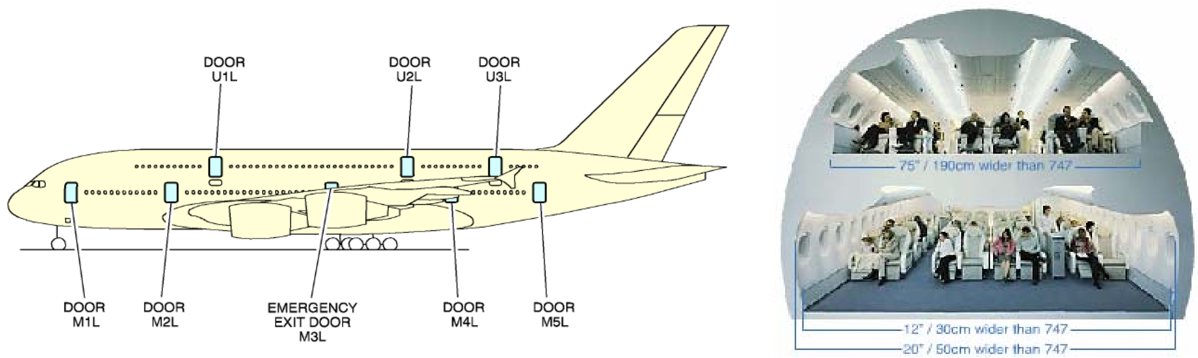
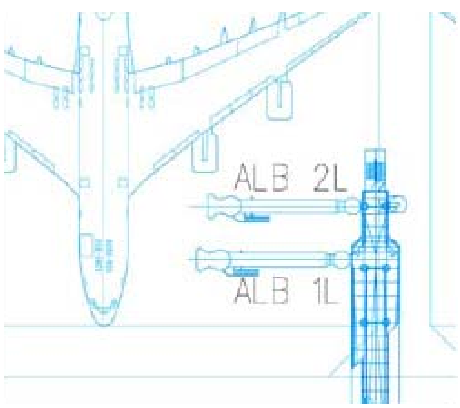


Figure 6 - A380 Door Arrangement



With two loading bridges installed at each gate, namely 1L and 2L as shown in the Figure 7, different combinations of upper and lower decks doors were reviewed in terms of the total time required for boarding/disembarking and the scale of modification and construction. Flexible combinations of bridge operations serving M1L, M2L and U1L doors were eventually considered to be feasible and economical implementable. The possible operation modes of the loading bridges are listed in Table 5 for reference:

Figure 7 - Aircraft loading bridge arrangement

Table 5
Different Bridge Operation Modes serving A380

	Passenger Door		
	M1L	**M2L**	**U1L**
Mode 1	Bridge 1L	-	-
Mode 2	Bridge 1L	Bridge 2L	-
Mode 3	Bridge 1L	-	Bridge 2L
Mode 4	-	Bridge 1L	Bridge 2L

Major modifications involved

In view of the operation modes above, the major scope of modification works on the aircraft loading bridges were identified.

- Lifting Column

Loading bridge 2L serving upper deck door U1L was considered to be one of most effective operation modes for A380. As specified in the A380 Airplane Characteristics (AC) Manual issued by Airbus [1], the door sill level of U1L door is 8.03 meters measured from the respective ground level (under the configuration of 300 tonnes aft the centre of gravity of the aircraft). The loading bridges at the gates before any modification could serve up to 5.5 meters, capable of reaching B747-400's front passenger door with maximum door sill level of 5.2 meters

Figure 8 - Modified Bridge

With such a level difference between the reachable height of 5.5 meters and the required height of 8.03 meters, the existing single-paired lifting column at bridge 2L was replaced with a double-paired column structure with each pair of columns operated one after another to reach the upper deck of A380 as shown in Figure 8.

- Relocation of service stair

With the use of computer software to simulate the bridge layout on the apron, the clearance between the two loading bridges was estimated to be around 900mm when doors M2L and U1L are being served (Mode 4). In order to increase this clearance, the service stair originally located at left side of bridge 2L was relocated to the right side for greater safety during docking and parking conditions.

- Anti-collision system

  The aircraft loading bridges were fitted with additional sets of limit switches and infrared sensors to trigger alarms and stop aircraft loading bridge movement when limits had been reached to prevent a collision to the A380 aircraft engine or wing and also bridge-to-bridge collisions, as shown in Figure 9.

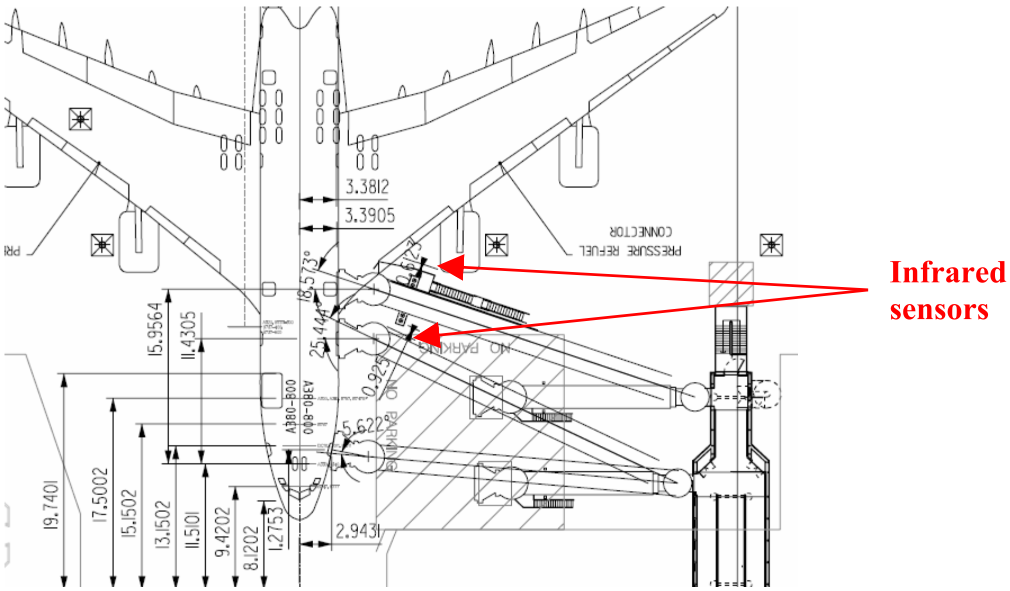


Figure 9 - Anti-Collision Sensors

Challenges faced during the design and modification stage

- Compatibility to both A380 and all existing aircrafts.
- All the settings for existing aircrafts had to be maintained and verified after any modifications were done to the bridges.
- Service stairs had to be modified with infrared protection sensors to maintain a critical distance between bridges 1 and 2, and the bridge 2 and aircraft.
- Tight construction schedule under the airport's operating environment.

3.4 Modification of Fixed Ground Power System for the A380

The Fixed Ground Power (FGP) system at the HKIA for the frontal and remote stands around the Passenger Terminal Building (PTB) is a centralized system that converts 380V, 50Hz input to 960V, 400Hz output for electrical distribution.

Each frontal stand is fitted with a 90kVA gatebox, with a plug at Bridge 2L and 120kVA gatebox with two plugs at Bridge 1L. Both gateboxes convert the 960V, 400Hz input to 200V, 400Hz for feeding power to individual aircraft.

According to the A380 Airplane Characteristics (AC) Design Manual [1], the ground electrical power requirements are:

(a) 3 phase power supply, 115V, 400Hz.

(b) 4 x 90kVA standard ISO R461 receptacles.

As recommended by Airbus, the minimum electrical power requirements for the basic aircraft systems is 180kVA but, depending on ground operations, additional ground power will be required.

Figure 10 - Standalone FGP Unit

In view of the capacity of the centralized system and complexity of the modifications, two additional 90kVA standalone converter units were installed at apron level for each stand. Hence, each stand has 300kVA ground power supply by using the standalone units, as shown in Figure 10, in addition to the existing bridge-mounted FGP system.

To minimize the impact to different ground operations, such as fuelling, catering, fresh water supply and cargo handling when the aircraft is being serviced, a pop-up system was used near the parking line. This system can be lowered flush to the apron level leaving the area free for traffic.

4. RELOCATION OF INFRINGING OBSTACLES AND MODIFICATION OF JET BLAST FENCE

Based on the compatibility study, a detailed survey was carried out to confirm the exact relocation requirements of the infringing obstacles including lamp posts, sign posts, wall structures, jet blast fences and airside roads. Conventional construction methods were deployed for the relocation/modification work but had to be carried out under airfield operational constraints to minimize the impact on normal operations.

5. OTHER RAMP SERVICES

Refueling

Refueling operations are carried out through four under-wing pressure connectors at 40 psi. As the configuration is similar to the B747-400 aircraft, no modifications for the A380 aircraft were required.

Low Pressure Preconditioned Air

The A380 requires a minimum of 40-50 kPa of low pressure preconditioned air. At HKIA, the five Code F frontal stands are equipped with two preconditioned air units with a 83 kPa rating. Two additional mobile PCA units will be provided to service the A380.

Toilet and Waste Service

The A380 aircraft capacity for the toilet and waste service is 2500 litres, double the capacity of a B747-400. The ground service operators at HKIA have purchased larger capacity vehicles to service the A380.

Other GSE vehicles

Based on the new requirements of the A380, the ground service operators at HKIA have also upgraded or purchase new Ground Service Equipment such as catering trucks, cargo loaders and tow tractors to service the A380.

6. CONCLUSION

With forward planning and a comprehensive compatibility study, the short falls of HKIA's facilities in meeting the operational requirements for the A380 were identified shortly after the launching of the new aircraft in 2004. This was followed by a technical study of available options and an optimized detail design for a series of modification and enhancement projects. The modification and enhancement works were subsequently implemented under airport operational constraints and were completed on time and within budget in mid 2006. The first A380 test flight landed safely in HKIA on the 18 November 2006 and the testing of all new facilities and operating procedures were satisfactory carried out with only minor fine tuning required in a few of the facilities.

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4. Boeing 747 Airplane Characteristics for Airport Planning, Document D6-58326-1 (Revision D, December 2002) http://www.boeing.com/commercial/airports/747.htm3.3 Modification of Aircraft Loading Bridge.